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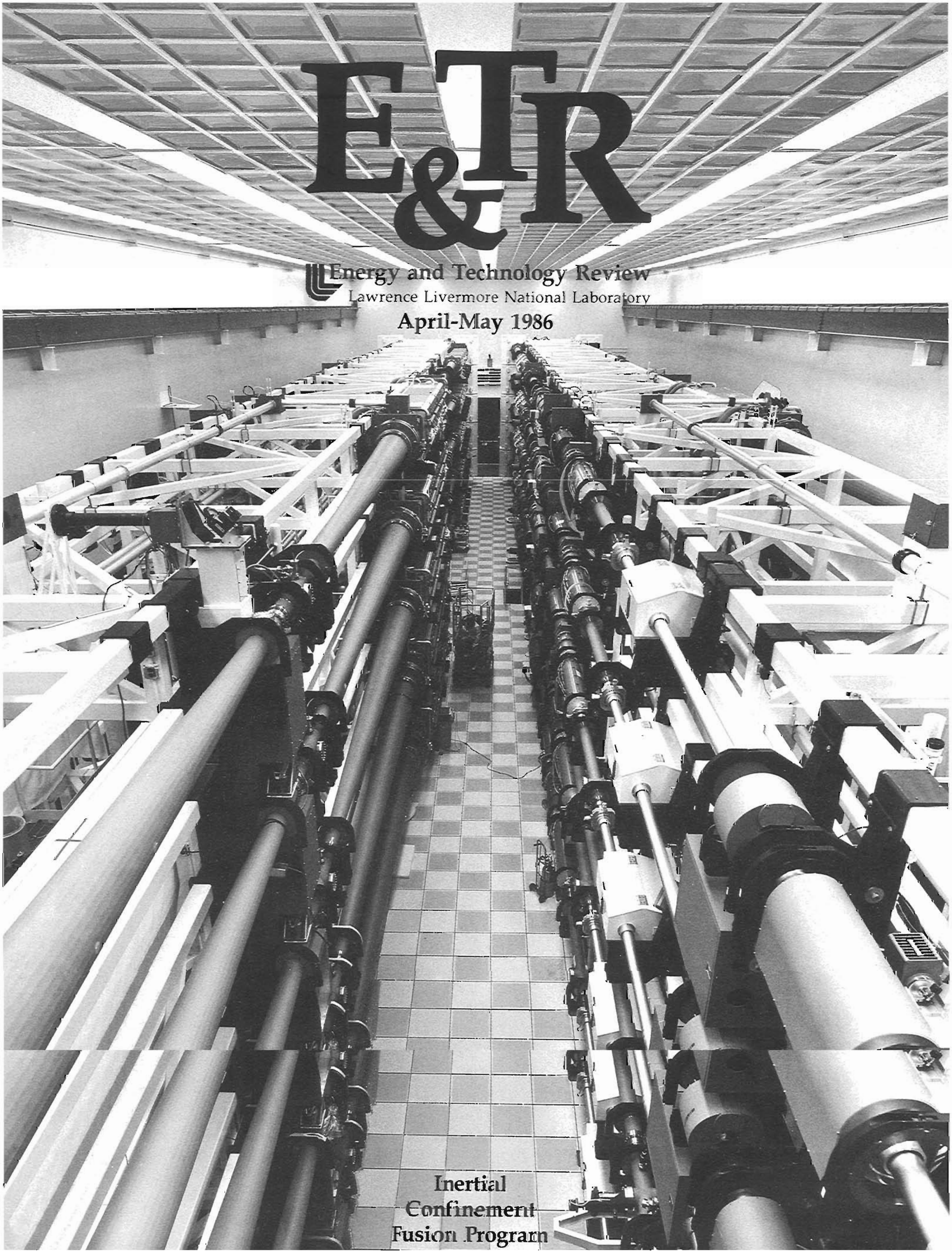

Inertial Confinement Fusion Program

LEAF Computer Facility

The LEAF computer system is used to reduce and analyze data collected by the hundreds of sensors on the Nova laser's two target chambers. LEAF has freed scientists from many of the routine tasks of data management, giving them more time for interpreting experimental results.

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The Laser Experiments Analysis Facility (LEAF) has been developed to satisfy the needs of the physicists and engineers who work with the data generated with the Nova high-energy laser facility. This secure, powerful computer system is highly interactive and designed for speed and ease of use. The user interface to the system is simple, and allows the user to select the desired function from his office terminal by choosing a menu option, punching in single-key yes/no answers to preprogrammed questions, or pressing a function key. LEAF has high-speed electronic links to the Nova control and data-acquisition computers and to the Livermore Computer Center (the Octopus system), so that it can not only speedily acquire experimental data but can also transfer them to more powerful computers for additional analysis and study.

System Overview

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design of the overall system (Fig. 1). Since LEAF produces classified output, its main computers (a VAX 11/785 and

a PDP 11/34) and its storage and archival facilities are in a vault; they are mechanically isolated from the system's peripherals outside the vault during nonworking hours. The VAX 11/785 is used for data processing and analysis, and the PDP 11/34 controls a Perkin-Elmer microdensitometer system to digitize film data. (Most of the data obtained by Nova's diagnostic instruments are recorded on film.) The digitized data are stored in files on the PDP 11/34 and then sent, via an intercomputer network, to the VAX, which, with four gigabytes of disk storage, can hold hundreds of these files. Data files are archived on magnetic tape using the system's two high-density magnetic tape drives.

LEAF provides a variety of graphics output devices that are essential for data analysis. Four Ramtek color monitors, with trackballs for interactive graphics, provide color-enhanced displays of film data arrays. A Dunn color copier can provide hard copy of these displays. Each LEAF terminal is a VT100 Retrographics machine, which provides high-resolution graphics as well as standard terminal functions. Versatec electrostatic plotters provide hardcopy output. Each plotter is driven by a random-element processor that makes most of the calculations necessary to

output. Each plotter is driven by a random-element processor that makes most of the calculations necessary to

construct a raster plot from vector data; this provides for increased graphics-output speed and reduced load on the main VAX. Letter-quality printing can be done on a LEAF high-quality printer, or the text file can be transferred electronically to a Wang word processor, which also has a high-quality printer.

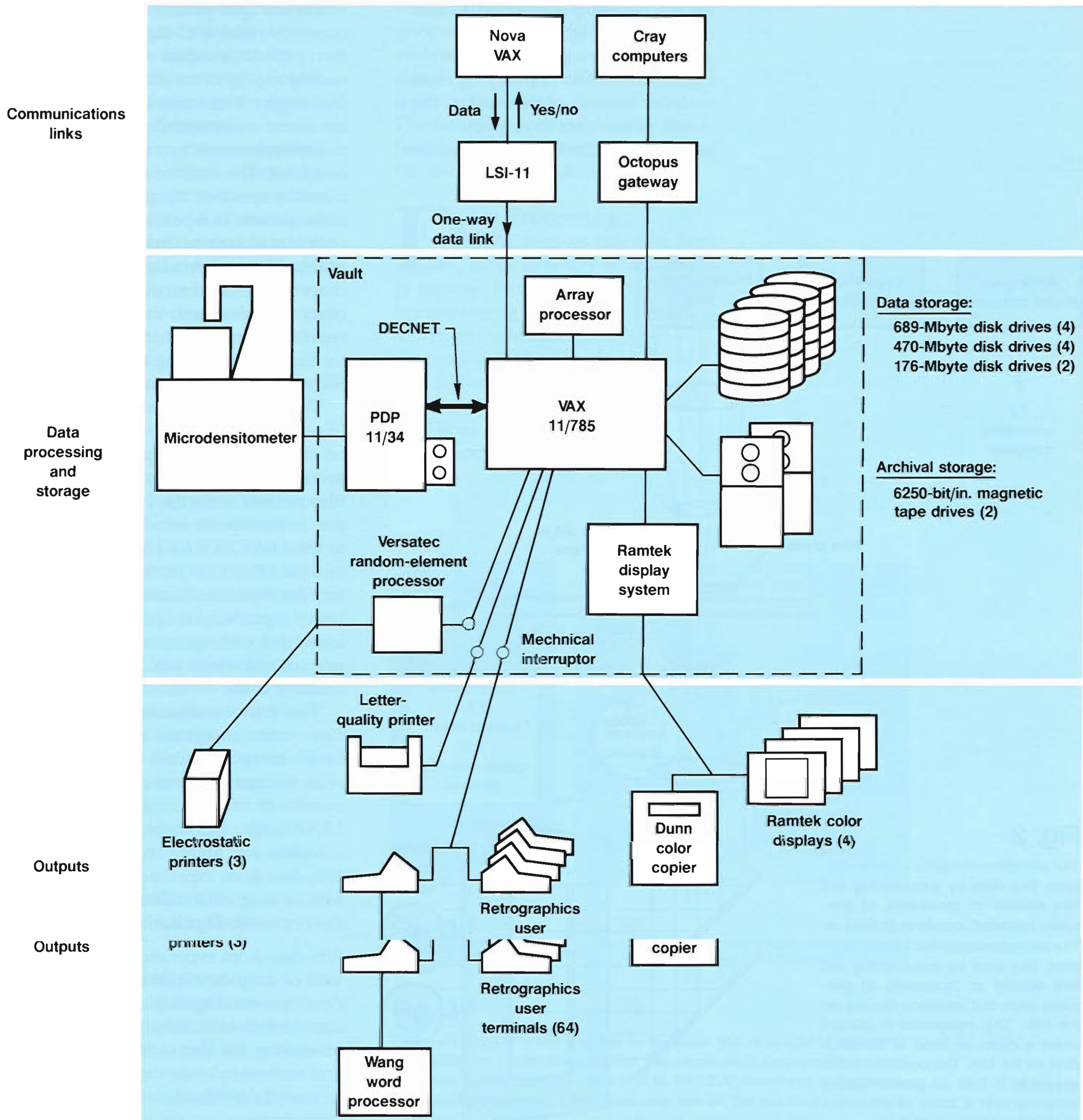
The LEAF VAX communicates directly with the unclassified Nova VAX, by a one-way (incoming) data link, and with the Cray computers of the Octopus system. These links are designed for rapid and efficient data transfer from Nova to LEAF and then to the Laboratory's Cray computers.

Film Microdensitometer

Data from Nova experiments are primarily three dimensional (*x,y,z*), and include the output of imaging devices (e.g., x-ray

Fig. 1

LEAF is a secure data-processing system. Its main computers and archives are contained within a vault and are mechanically isolated from peripherals during nonworking hours. LEAF's communication link with the unclassified Nova computer is a unique one-way system that prevents unauthorized access to classified data.



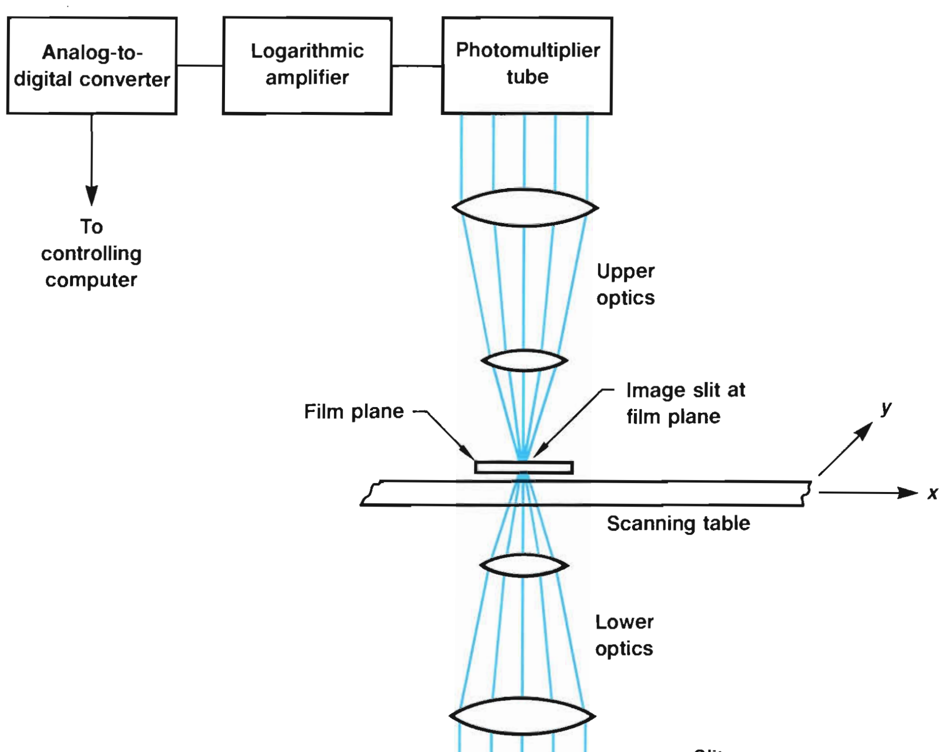
microscopes, x-ray pinhole cameras, laser focal-spot cameras) and time-resolving diagnostics (e.g., streaked x-ray and optical spectrometers). This output is recorded on film. However, quantitative analysis of the data requires that the density (darkness) variations on the film be converted to a computer-readable form.

Therefore, the film data are digitized. First, the transmission of a known light source through a small region of the film (a pixel) is measured. The logarithm of this transmission (film density), together with the location of the pixel, is then stored as raw data in computer-readable (digitized) form. Calibration data are used to equate each density value to the corresponding exposure that darkened the film.

This process is accomplished with the microdensitometer scanning assembly shown in Fig. 2. The lower optical assembly projects a small region of light on the sample plane. The upper optical assembly collects all light transmitted through the region and sends it to a photomultiplier tube where the light produces a small current. Analog and digital circuitry then produce a digital value corresponding to the film density for that region. This value and its location are stored automatically by the microdensitometer's controlling computer. The scanner table is then moved a specified distance, and the measurement is repeated. After a set of points along one dimension of the film has been digitized, the table is moved a specified amount in the other dimension and the process is repeated. Typical density array sizes for films from imaging diagnostics are 500 rows by 500 columns.

The density data sets from each film are stored initially in files on disk on the PDP 11/34 computer. After several films have been digitized, the files are sent from the PDP 11/34, via the intercomputer network DECNET, to the LEAF VAX for processing and analysis. The PDP 11/34 is used for film digitizing because the heavy input/output operations associated with operation of the microdensitometer would bog down terminal traffic on the VAX.

This microdensitometer was the first system of its kind at LLNL to be electronically linked to a data-reduction and analysis computer system. Its integration into the LEAF facility has made possible the complete and timely analysis of all film data from experiments and from tests of diagnostic instruments under development. Digitization, data
film data from experiments and from tests of diagnostic instruments under development. Digitization, data
transfer between computers, and processing are almost fully automated, and turnaround time from digitization to analysis of film data is merely a few minutes.



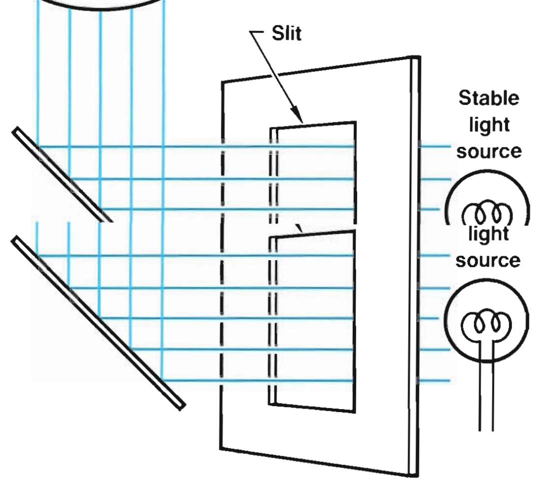


Fig. 2

The microdensitometer system digitizes film data by establishing the film density at thousands of precisely recorded locations (pixels) on
The microdensitometer system digitizes film data by establishing the film density at thousands of precisely recorded locations (pixels) on
the film. The equipment is placed under a clean air hood to minimize dust on the film. The scanning table assembly is built on granite blocks weighing over a tonne to provide a positioning accuracy of 2 μm.

Communication Links

A unique feature of LEAF is its high-speed communication links with the Nova unclassified control-system computers and with the secure Cray computers in the Octopus system. LEAF communicates with the Crays by means of the LLNL Octoport system, which allows transfer of files to and from the VAX and Cray computers; the transfer can be initiated at either side. Nova data are used on the Octopus system as the input for complex analysis or modeling codes. LEAF was the first computer system to make use of Octoport.

LEAF's other communication link allows files of raw data collected by the Nova data-acquisition computers to be transferred to LEAF shortly after they are created. This vital link to the Nova unclassified system is unique in that it allows file transfers (one way only) from the unclassified computers (Nova) to a classified system (LEAF) without requiring changes in the operating system software of either system. A functional diagram of the Nova-LEAF communication link is shown in Fig. 3.

The LSI-11 microprocessor serves only as a "one-way valve" between LEAF and the Nova computers; programs in the LEAF VAX and one of the Nova control-system VAXs perform the actual file transfer. A program on the LEAF VAX is constantly running, awaiting signals from the Nova VAX that a file is ready to be transmitted. An operator at the Nova VAX initiates the file transfer. The two programs can transmit all the files for a typical Nova experiment in just a few minutes, a great improvement over file transfer via hand-carried magnetic tape or other means.

LEAF Software
LEAF's VAX software

LEAF Software

LEAF's VAX software capability includes many programming tools that are available to all users. The system provides compilers for Fortran, Pascal, Basic, and C, so that users can program in any of these languages. The LEAF system also has extensive libraries of subroutines and procedures for graphics and numerical analysis. Finally, all users have access to a fourth-generation, relational database management system.

These programming tools are used in many different applications. However, LEAF's main capability is an extremely powerful system of software (developed from the programming tools) for processing, analyzing, displaying, and archiving data. It is heavily used by both experimentalists and theoreticians. The following sections describe the functions of the software in evaluating Nova experimental data.

Data Processing

LEAF receives raw data from Nova in binary form, either as digitized film data or as the output (corresponding to voltages, currents, etc.) from the diagnostics with electronic recording modules. These raw data values are reduced to quantitative descriptions of physical conditions of the laser-irradiated targets and then stored for later analysis.

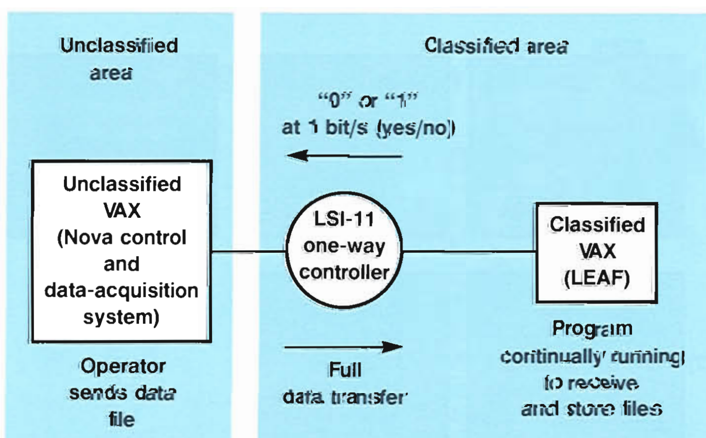


Fig. 3

Fig. 3

The heart of LEAF's one-way link to the Nova VAX is an LSI-11 microprocessor with an associated program that allows each data word to pass at maximum speed from the Nova VAX to the LEAF computer. In the opposite direction, however, it transfers only one bit (for yes/no replies) once a second.

Reducing the data is a three-stage process (Fig. 4). First, binary data are extracted from the files, and detector outputs are separated from control and status bits. Second, the binary data are converted to analog values and labeled according to the sensor from which they originated. Third, the analog signal is converted to a physics quantity that characterizes conditions at the target. In this form, the data are archived for analysis and display.

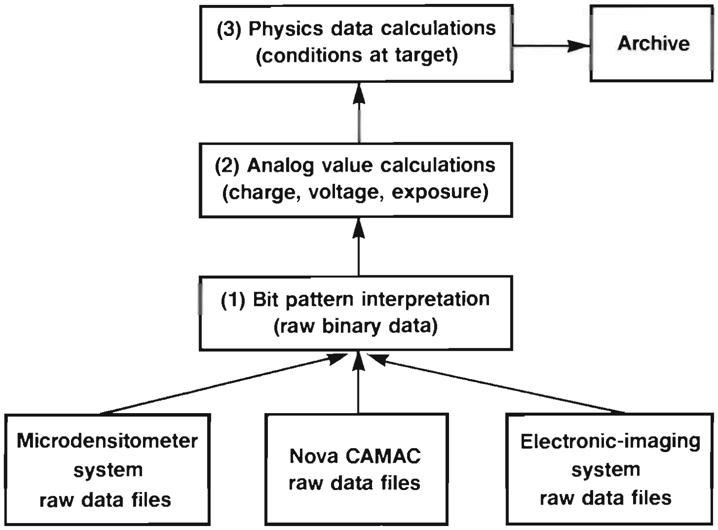


Fig. 4

LEAF has three levels of data-processing software. At the first, lowest level, raw data are taken from the three primary sources and the bit patterns are interpreted into status and data forms. (The Nova CAMAC is the computer-automated measurement and control system, an instrumentation standard to which all Nova electronic recording instruments conform.) At the second level, calculations are performed, using on-line reference data on instrument design and calibration, to convert the instrument readouts to analog values (e.g., voltage). At the third level, calculations are performed, to obtain the physics data that describe conditions at the target. The results of these calculations are stored.

This data-reduction process requires a large set of programs to manipulate the extensive labeling and calibration parameters, which are stored in a data base. The task of data reduction is made possible by integrating all phases of LEAF processing and analysis software with a relational data-base management system. The one used at LEAF is the commercial ORACLE system.

In a relational data base, the data are stored in tables. Each column of the table corresponds to an entity, and each row implicitly implies a relation between the columns. For example, a table in which one column is the name of an assembly and the other columns are the names of components' parts implicitly contains the relation of a parts list. The relational data base allows different tables to be related to each other by the use of corresponding columns in both tables. This relational scheme of storing data is ideal for a scientific data environment for which many complex and interrelated data sets must be readily available. The data sets required for LEAF are:

- Diagnostic instrument component lists and corresponding calibration data.
- Mapping between diagnostic detector names and the corresponding electronic recording devices.
- Correspondence between data files and corresponding experiment number and originating instrument (this correspondence is used in data analysis).
- Experimental summary data labeled by experimental sequence and analysis).
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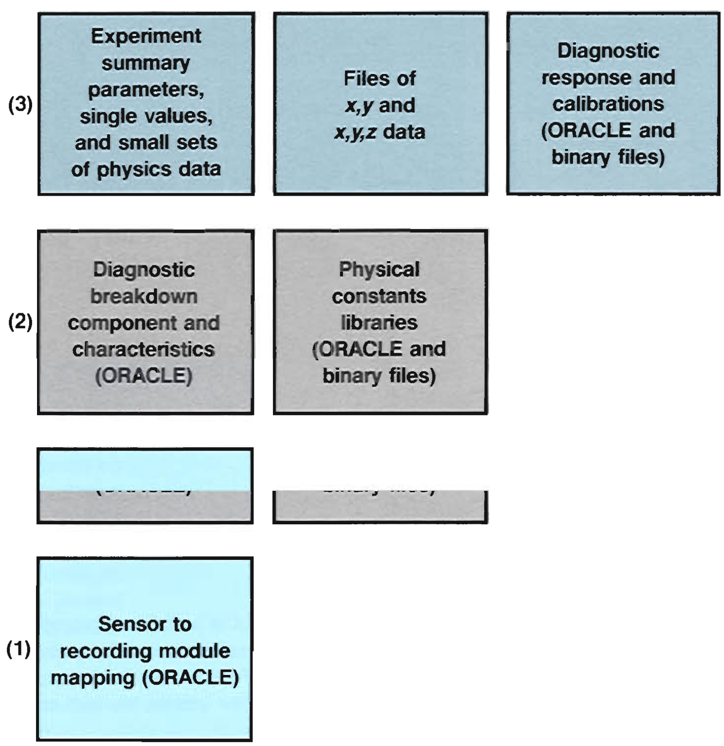
Figure 5 illustrates how the different data bases connect the different levels of processing and data archiving.

Fig. 5

Different data bases on the LEAF VAX are used at different levels of processing. The numbered levels in this figure correspond to those in Fig. 4.



The data-processing software at LEAF provides the experimentalists with a variety of tabular and graphic output, the most sophisticated being the color-enhanced displays of processed film data (see Fig. 6).

Electronic Shotbook

To allow examination of all archived physics data (i.e., data describing conditions at the target), we developed a very sophisticated and powerful program based on the relational data base. It is named the Electronic Shotbook because it replaces, for the most part, the paper notebooks (shotbooks) that were the means of data archiving for many years. The Electronic Shotbook allows LEAF users to share all physics data archived on LEAF and to examine it at their own terminals. Users select the data to be examined simply by specifying the instrument name and shot number (or shot series or subseries). The Electronic Shotbook, now widely used by all researchers associated with the Nova facility, has made LEAF a key asset of the Laser program.

The user interface for the Shotbook is a set of menus, an example of which is shown in Fig. 7. The menus lead the user, step by step, to successively more detailed ranges of data; they also enable the user to perform various functions by pressing a single key on the terminal. Through the menus, the user has access to various Shotbook displays (Figs. 8 and 9), which can show any of the following three types of data:

- Scalar data: single alphanumeric values (e.g., target dimensions, laser energy incident on target). These values are stored in tables of the ORACLE data base.
- Profile data: sets of *x,y* pairs (e.g., x-ray spectra, laser power history, optical emission spectra). Small sets are stored in the ORACLE data base.

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Profile sets with a large number of *x,y* pairs are stored in a standard-format file readable by the Shotbook.

- Contour data: sets of *x,y,z* values, created by processing codes. Contour data are stored in a standard-format binary file readable by the Shotbook. Data are displayed as standard line contour plots, and the user can select horizontal and vertical line plots of the contour data using the terminal's graphics cursor.

Whereas all profile and contour data files are produced by the processing codes, some of the scalar data must be entered into the

(a) (b)

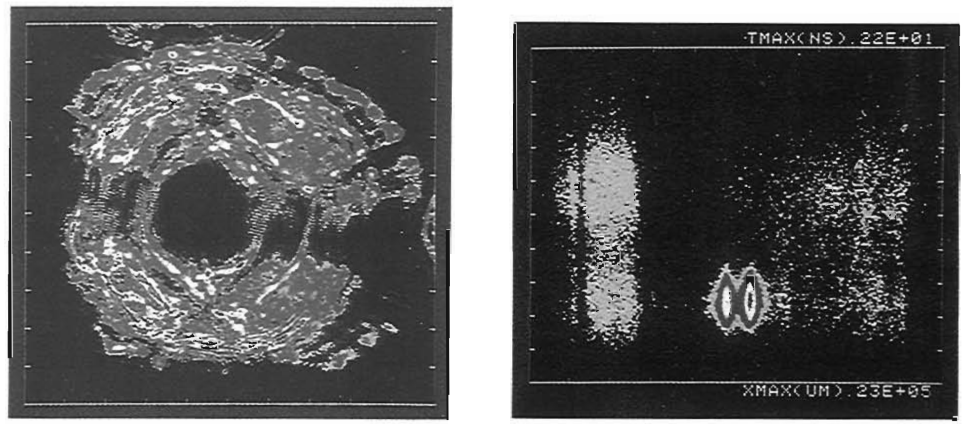

Fig. 6

Black-and-white images of the color-enhanced displays of data available on the Ramtek terminals. (a) The light-intensity distribution at the far field of a Nova laser beam. (b) A time-resolved spectrum from an x-ray laser experiment.

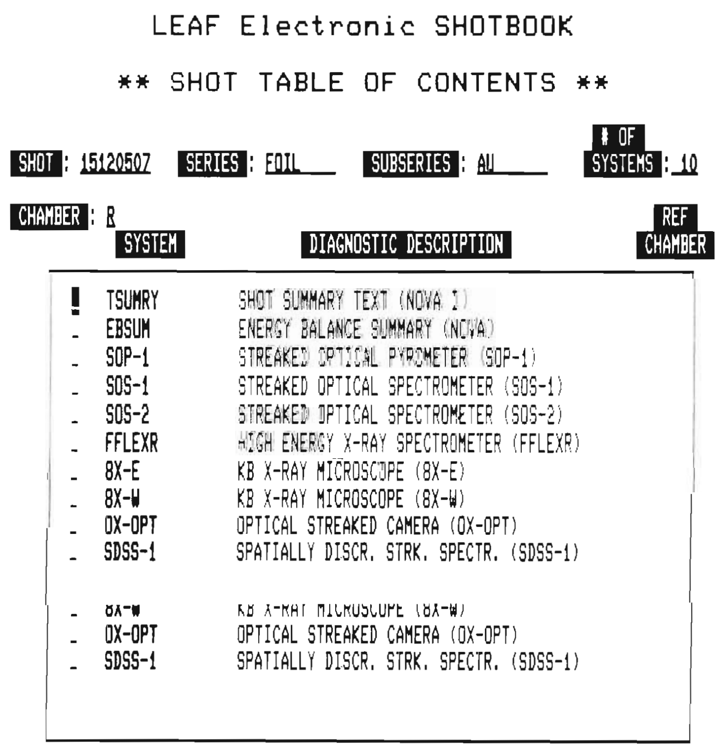

Fig. 7

This menu page from the Electronic Shotbook offers the user information from a choice of different diagnostic instruments used in an experiment.

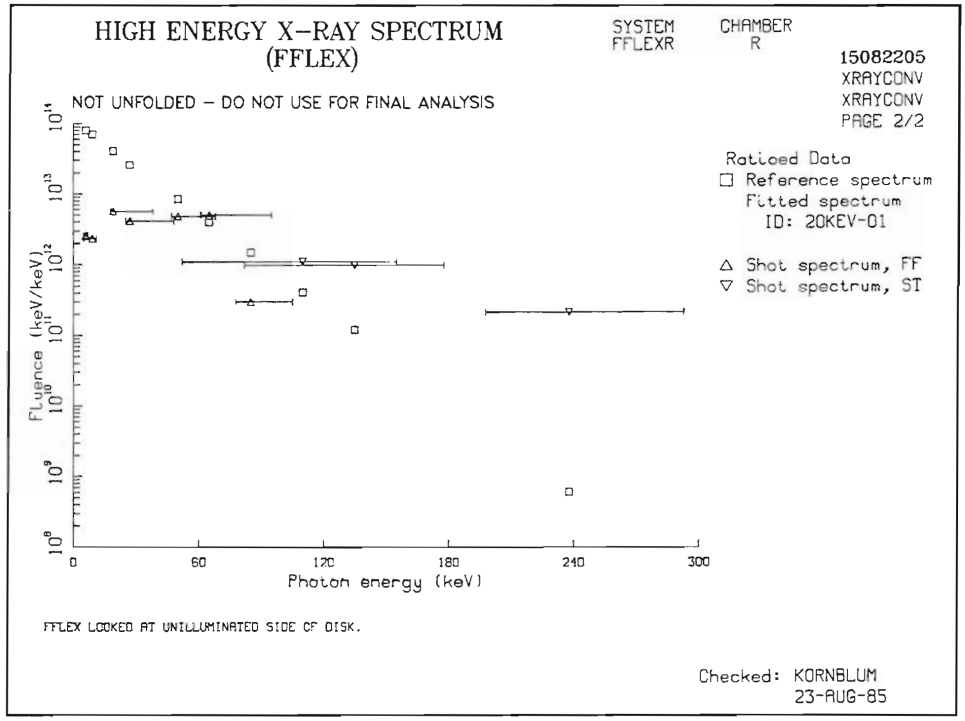

Fig. 8

This Electronic Shotbook display of data recorded by a high-energy x-ray spectrometer shows crucial parameters such as error ranges on data and verification.

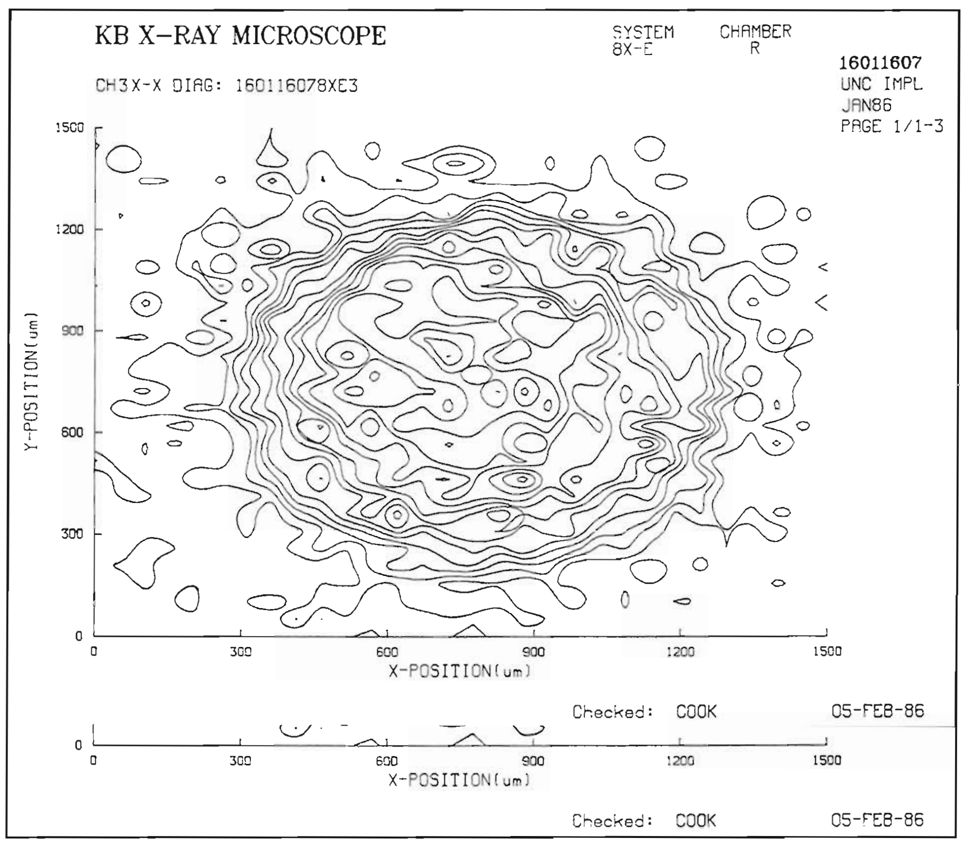

Fig. 9

The contours in this Electronic Shotbook display (recorded by an x-ray microscope) show the shape of x-ray emission from the target as it was irradiated.

ORACLE data base, using the same terminal screen forms used for displays. Security is therefore required at various levels on the data base table, so that all users can examine the data but only individuals responsible for certain subsets of the data can enter, alter, or delete it. We have developed such a system using the table security features of ORACLE. The protection structure can be changed at any time to accommodate new personnel or instruments.

The Shotbook allows the user to make high-resolution hardcopies of all terminal displays using a single-keystroke command. These copies are produced on the VERSATEC printer plotters. In addition to the various diagnostic displays, the Shotbook also provides text files for shot summaries, prepared by the responsible physicist.

Diagnostic Design Software

LEAF provides Laser program physicists with the wide range of software and physical data required for the design of an experiment with Nova and for the design of the instruments that diagnose target performance. All diagnostic design codes provide detailed graphic output of the results. For example, Fig. 10 shows the spectral response of the filters and mirrors in a broadband x-ray spectrometer channel.

Conclusion

LEAF combines a complex relational data base, a gallery of software, state-of-the-art hardware, and ingenious communication links in a powerful, sophisticated, well-designed computer system. Although the LEAF system itself is complex and sophisticated, its simple user interface minimizes the need for knowledge of the internal details of the system. LEAF frees laser scientists from many of the routine tasks of data management and allows them more time for interpretation of the experiments.

Key Words: computer system—Nova, Octopus; data—analysis, management, recording, retrieval, storage; data base—ORACLE, relational; Electronic Shotbook; Laser Experiments Analysis Facility (LEAF); laser—experiment, Nova; Livermore Computer Center; Octoport.

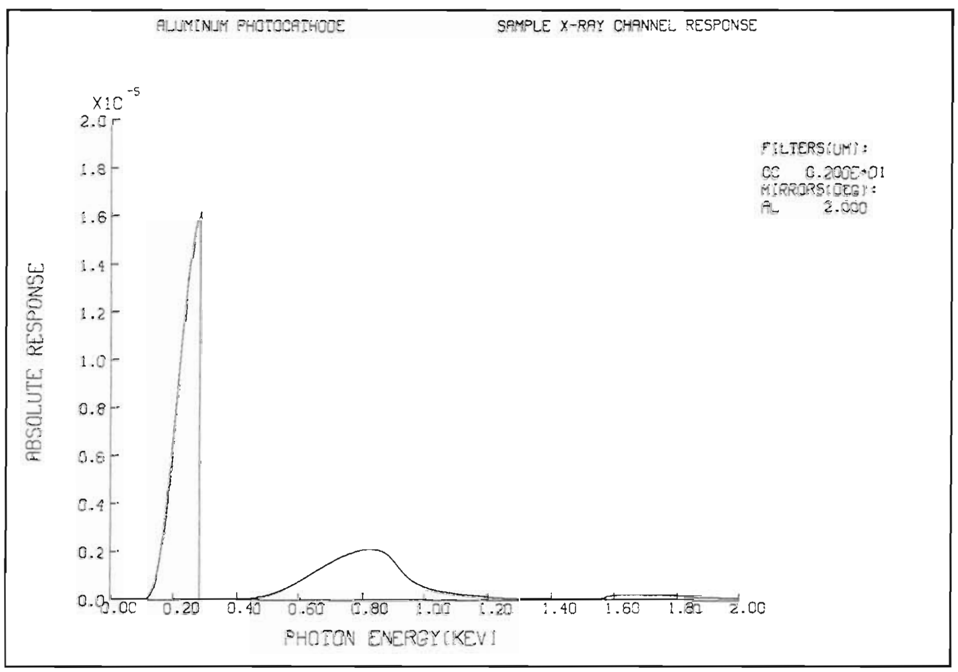

Fig. 10

This plot of the response function for a broadband x-ray spectrometer channel was calculated with LEAF software for the design of diagnostic instruments.